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(54) **Catalyst precursor production.**

(57) Normally sparingly soluble magnesium alkoxide is solubilized in alkanol by the additional presence of certain acidic materials. The resulting solution is used to prepare a mixture of substantially spherical particles, substantially free of fines, containing an adduct magnesium alkoxide. The particles are converted by conventional methods to a procatalyst precursor of an olefin polymerization catalyst of high activity and high selectivity to stereoregular polymer whenever appropriate.

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This Invention relates to the production of a precursor of an olefin polymerization catalyst. More particularly, the Invention relates to the production of a magnesium alkoxide compound which is a useful precursor of a procatalyst of a catalyst which can be used to produce a polyolefin product of good morphology.

Many olefin polymerization catalysts are known which comprise a solid component containing at least magnesium, titanium and chlorine are an activating organoaluminum compound. These catalysts are conventionally referred to as supported coordination catalysts or catalyst systems. Their activity and stereo-specific selectivity is generally improved by incorporating an electron donor, i.e. a Lewis base, in the solid component and by employing as a third catalyst component an electron donor which is complexed in whole or in part with the activating organoaluminum compound. The solid titanium-containing compound is referred to as a "procatalyst", the organoaluminum compound, whether complexed or not, is referred to as the "co-catalyst" and the third component electron donor, whether used separately or partially or totally complexed with the organoaluminum compound, is referred to as a "selectivity control agent" (SCA).

Supported coordination catalysts of this type are used to produce olefin polymers in high yield and, in the case of polymers of propylene or higher α -olefins, to produce highly stereoregular polymers. A highly active coordination catalyst is particularly important because it need not be extracted from the polymer in a de-ashing step. It is important to produce stereoregular polymers in order to avoid a process step of extracting atactic polymer when α -olefins of three or more carbon atoms are polymerized.

Many combinations of procatalysts, co-catalysts and selectivity control agents produce active catalysts. However, considerable experience has resulted in certain materials being of greater interest. The procatalyst is typically some chemical combination of magnesium chloride and titanium tetrachloride and the electron donor is frequently an aromatic ester such as ethyl benzoate or ethyl p-toluate. The co-catalyst is frequently an aluminum trialkyl such as triethylaluminum or triisobutylaluminum which is often complexed with a portion of the selectivity control agent which is also, typically, an aromatic ester. While variations in any of these catalyst components will influence the performance of the catalyst which results, the component which seems to offer the greatest opportunity for modification to produce greater catalytic activity is the procatalyst.

Preferred methods of producing procatalysts are the subject of a number of U.S. patents including US-A-4,329,253, US-A-4,393,182, US-A-4,400,302 and US-A-4,414,132. These procatalysts, useful in the production of olefin polymerization catalysts of high activity and stereoregular selectivity, are generally prepared by contacting a magnesium compound, titanium tetrachloride and the electron donor in the presence of a halo-hydrocarbon. The resulting particles are then contacted with additional titanium tetrachloride before washing off the excess titanium tetrachloride with a light hydrocarbon solvent, e.g. isooctane, and drying the procatalyst.

Even when an olefin polymerization catalyst composition of acceptable catalytic activity and stereospecific selectivity is obtained, other considerations are important. It is highly desirable to produce a polyolefin product having a specific morphology, e.g. a polymer product in the form of spheroidal particles of uniform size, without too many small, irregular polymer particles such as fines. It is known that in olefin polymerizations the morphology of the polymer product is a replica of the morphology of the catalyst employed in its production. It is also known that the morphology of the catalyst is dictated to a considerable extent by the morphology of the procatalyst and particularly by the morphology of the magnesium compound used as the support. Thus, production and use of a magnesium compound of desirable morphology will generally result in the ultimate production of a polyolefin product of desirable morphology.

Various procedures are available for producing a magnesium compound support, or the procatalyst produced therefrom, of improved morphology. GB-A-2,101,610 reacts a solid particulate material with an organic magnesium compound, treats the resulting magnesium compound with oxygen, carbon dioxide or a hydroxyl compound and reacts the treated product, simultaneously or in sequence, with a carbonyl compound or a transition metal compound. In another process a dispersion of solid magnesium alkoxide particles in a suitable liquid medium are employed as the feed for a spray drying process, but the presence of solid particles is a disadvantage because of the tendency of the particles to clog the fine orifices of the spray drying equipment. In US-A-4,540,679 a magnesium compound, i.e. a magnesium hydrocarbyl carbonate, is used as a support, produced by reacting a suspension of magnesium alkoxide and carbon dioxide. In US-A-4,771,024 a solution of a carbonated magnesium alkoxide is produced by bubbling carbon dioxide through a suspension of magnesium ethoxide in a diluent such as an alcohol. The resulting solution is used to impregnate a solid inorganic support or to produce particulate magnesium ethoxide by spray drying. The support particles thereby obtained are of desirable morphology and are useful precursors of olefin polymerization procatalysts. However, some degree of care must be taken during the reaction of the magnesium alkoxide and the carbon dioxide because of the exothermic nature of the reaction and the viscous nature of the solution which results.

According to the present invention there is provided a process for producing an alkanolic solution of an adduct of magnesium alkoxide and an acid selected from sulfur dioxide, formaldehyde, aluminium alkoxide and trialkylborate, wherein the molar ratio of acid:magnesium alkoxide is from 0.4/1 to 2/1 and the concentration

of magnesium is from 1% to 8% by weight based on the weight of the solution. This solution is used to produce, by conventional methods, a solid magnesium alkoxide compound composition of the desired morphology. Use of this composition as a precursor of a transition metal olefin polymerization catalyst, particularly for the polymerization of olefins of three or more carbon atoms, results in a polyolefin product which also exhibits desirable morphology.

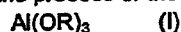
The process of the invention comprises the solubilization of a magnesium alkoxide in an alkanol, particularly ethanol, by interaction of the magnesium alkoxide with certain acidic materials. The magnesium alkoxide solution is then converted to a solid product useful as a precursor of olefin polymerization catalysts by a number of procedures. Magnesium alkoxides, particularly magnesium ethoxide, are known to be a useful precursor of olefin polymerization procatalysts. Solid magnesium alkoxide products are produced from solutions of magnesium alkoxide by procedures such as spray drying, freeze drying and impregnation of silica-containing particles. These solid products are of a desirable morphology and are utilized to produce olefin polymerization procatalysts and ultimately olefin polymers which also exhibit desirable morphology. However, the solubility of magnesium ethoxide in ethanol, for example, is only about 0.1% by weight magnesium and such a solution is too dilute to be efficiently used in the production of magnesium alkoxide solids for olefin polymerization procatalysts. The low solubility of magnesium alkoxides in alkanol is thought to be due to their polymeric nature. It seems likely that the acid reacts with the polymeric magnesium alkoxide to form an adduct and the resulting species has a higher solubility in alkanol.

Magnesium alkoxides suitable for use in accordance with the present invention are those wherein each alkoxy group has from 1 to 4 carbon atoms. The alkyl moiety of the alkoxy group can be straight-chain or branched and illustrative alkoxy groups are methoxy, ethoxy, 1-propoxy, sec-butoxy and n-butoxy. Magnesium methoxide and magnesium ethoxide are preferred magnesium alkoxides and magnesium ethoxide is particularly preferred. Other examples of magnesium alkoxides are the crystalline $Mg_4(OCH_3)_6(CH_2OH)_{10}X_2$, where X is a counter ion or ions with a total charge of minus two; for example, X can be Cl, Br, methacrylate, butyrate, acrylate, acetate, resorcinolate, 2,4-pentanedionate, propionate, benzoate or chloroacetate.

The alkanol in which the magnesium alkoxide is solubilized suitably is a lower alkanol of from 1 to 4 carbon atoms as illustrated by methanol, ethanol, isopropanol and sec-butanol. Methanol and ethanol are preferred and ethanol is particularly preferred. Although it is not necessary for the alkyl moiety of the alkanol to correspond to the alkyl moieties of the magnesium alkoxide, it is generally preferred to use magnesium alkoxides and alkanols of corresponding alkyl moieties. Thus, in a particularly preferred embodiment of the invention, magnesium ethoxide is used together with ethanol.

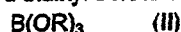
The solubilizing acid is a Lewis acid, that is, a compound capable of accepting a pair of electrons to form a coordinate covalent bond. Not all Lewis acids, however, are effective in ultimately producing olefin polymerization procatalysts. Some Lewis acids are not sufficiently active in solubilizing the magnesium alkoxide. Other Lewis acids, which are effective in solubilizing the magnesium alkoxide, are poisons for the olefin polymerization catalyst produced from the magnesium alkoxide. The trace quantities of these Lewis acids present in the magnesium-containing precursors of the catalyst preclude effective olefin polymerization. The acids which are useful solubilizing agents in accordance with the invention are sulfur dioxide, formaldehyde, aluminum alkoxide and trialkyl borates.

The sulfur dioxide is employed as a gas and typically a magnesium alkoxide and an alkanol are mixed and sulfur dioxide is bubbled through the resulting mixture to effect solubilization. When the acidic solubilizing agent to be used is formaldehyde, it is preferred to use an anhydrous form of formaldehyde, i.e. paraformaldehyde. The aluminum alkoxides which are useful in the process of the invention are suitably of the formula



wherein each R independently is alkyl of from 1 to 10 carbon atoms inclusive, e.g. methyl, ethyl, i-butyl, secamyl, hexyl or decyl. However, better results are obtained when each R is alkyl of from 1 to 4 carbon atoms and particularly preferred as the R group are methyl and ethyl. It is preferred, although not required, that when aluminum alkoxide is used to solubilize magnesium alkoxide in alkanol, the alkyl moiety of the aluminum alkoxide correspond to the alkyl moiety of the magnesium alkoxide and the alkanol. Such correspondence serves to minimize the possibility of ester exchange during the solubilizing process.

The preferred acidic solubilizing agent is a trialkyl borate ester of the formula



wherein R is as previously defined. Trimethylborate and triethylborate are the preferred members of this class, particularly triethylborate, and for the reasons stated above it is preferred that the alkyl moieties of the borate ester correspond to the alkyl moieties of the magnesium alkoxide and the alkanol.

The acid is employed in a quantity sufficient to provide from 0.4 to 2 moles of the acid per mole of magnesium (as the alkoxide) to be solubilized. Preferably, sufficient acid is employed to provide from 0.8 to 2.0 moles of acid per mole of magnesium.

The magnesium alkoxide and the acid are contacted in sufficient alkanol to permit complete dissolution of the magnesium alkoxide in the alkanol. Sufficient alkanol is provided to yield a solution containing from 1% by weight to 8% by weight of magnesium (present in the complex alkoxide) in alkanol, based on total solution. Preferred alkanol solutions are those containing from 2% to 6% by weight of magnesium on the same basis.

5 From a processing consideration the production of reasonably concentrated solutions of the magnesium alkoxide compound is preferred and the solutions are subsequently diluted with additional alkanol if more dilute solutions are preferred, for example, as for the spray drying process.

The dissolution of the magnesium alkoxide compound in alkanol is conducted by contacting magnesium alkoxide, the acid and alkanol at a moderate temperature. Substantial dissolution of the magnesium alkoxide, and often complete dissolution of the magnesium alkoxide if dilute solutions are to be formed, takes place at or about ambient temperature. Dissolution is more rapid if some form of agitation, e.g. shaking or stirring, is provided. In order to obtain complete dissolution at an acceptable rate it may be necessary to warm the mixture, for example up to about 80°C, more often up to about 60°C. However, a solution resulting from such warming will remain clear upon returning to ambient temperature.

15 In one embodiment of the process of the invention the magnesium alkoxide is provided as a preformed material. Several magnesium alkoxides of reasonable purity are available commercially and are used without any special purification or drying. The magnesium alkoxide, acid and alkanol are mixed and maintained at a suitable temperature until dissolution is complete. In an alternative embodiment of the invention, the magnesium alkoxide is formed in situ by the addition of elemental magnesium to the alkanol and acidic material. The metallic magnesium can be provided as chunks, turnings or in a finely divided form, e.g. 50 mesh or smaller, and the reaction of the metal with a portion of the alkanol is catalyzed by the presence of a material such as ferric chloride. In this embodiment it is typically desirable to employ a filtration step to remove insolubles introduced with the magnesium. In the embodiment where the acid is an aluminum alkoxide, the aluminum alkoxide is suitably also produced in situ by this method upon addition of elemental aluminum.

25 By whichever embodiment is utilized, the resulting material is a solution of the magnesium alkoxide compound, likely present in a complex with the acid, in alkanol. The concentration of the magnesium species is from 1% to 8% by weight magnesium, preferably from 2% to 6% by weight magnesium, based on total solution. The solution has a molar acid:magnesium ratio of from 0.4/1 to 2/1, preferably from 0.6/1 to 2.0/1.

30 The solution of magnesium alkoxide-acid in alkanol is then used to produce a magnesium alkoxide-containing solid to be utilized in the production of the olefin polymerization procatalyst by conventional methods such as impregnation, spray drying or spray cooling.

The spray drying process is conducted by procedures such as that described in US-A-4,771,024. The magnesium-containing solution to be spray dried is passed through a suitable atomizer to produce a spray or dispersion of droplets of the liquid mixture, a stream of hot gas such as nitrogen is arranged to contact the droplets to evaporate the solvent and the resulting solid product is collected. The atomization of the solution customarily takes place in the absence of water or oxygen and nozzle atomizers or spinning disk atomizers are usefully employed.

40 The temperature at which the spray drying takes place is controlled largely by the temperature of the gas employed to impact the droplets and will be of some importance in determining the physical nature of the spray dried product. For an ethanol solution of given solute content, for example, too high a spray drying temperature results in hollow, splintered particles. Too low a drying temperature will result in incomplete removal of solvent and particle agglomeration. Spray drying temperatures from 40°C to 120°C are satisfactory for the solutions produced according to the invention although temperatures from 50°C to 90°C are preferred.

45 The mechanical arrangement of the spray drying process is not critical. The hot gas may contact the droplets in a countercurrent manner although a co-current flow of the hot gas and the solution to be dried is usually preferred. In such an arrangement the atomizer is typically located near the top of a spray dryer and the hot gas is introduced at the top of the apparatus and is removed near the bottom. A major portion of the spray dried product is removed from the bottom of the apparatus by conventional procedures as by the use of a feeder valve or a conveyor. A lesser portion of the product is entrained in the hot gas and is recovered by passage of the gas through a cyclone separator. The alkanol is often condensed and recycled and the circulating gas is suitably reheated and returned to the top of the apparatus for reuse. A description of a conventional spray drying apparatus and conditions for its use is found in US-A-4,465,783.

55 The resulting spray dried product is predominantly magnesium alkoxide with a lesser amount of the acid. The physical form of the product will be substantially uniform particles having the general shape and appearance of a dried pea and a particle size of from 8 to 100 µm. It is characteristic of the magnesium alkoxide materials of one embodiment of the invention that the spray dried product will be uniform in size with no more than about 1% of the particles being outside the 8 to 100 µm range and the product will be substantially free of fines.

The spray dried product is probably an adduct of magnesium alkoxide with a reduced proportion of acid

as some or all of the acid is lost during the spray drying process. The spray dried product has a molar acid:magnesium ratio of up to 1.7/1, preferably from 0.3/1 to 0.8/1. Any remaining acid is not detrimental when the magnesium alkoxide compound particles are employed in the production of a procatalyst to be used in olefin polymerization.

Although spray drying constitutes a preferred method of producing the magnesium alkoxide-containing solid precursor of the olefin polymerization procatalyst, other methods are also useful. A second method of producing magnesium alkoxide containing particles of the desired morphology comprises impregnating an inert particulate support having the desired morphology with the alkanolic solution containing the magnesium alkoxide. Such inert particulate materials include inorganic materials such as oxides of silicon or aluminum and molecular sieves, as well as organic materials such as polyesters. The use of inorganic supports such as inorganic oxides is preferred. Such supports are typically used in the form of a dry powder having a particle size of from 10 to 250 μm and preferably from 50 to 150 μm . The inorganic supports are preferably porous and have a surface area of at least 3 sq. meters per gram and preferably at least 50 sq. meters per gram. They are preferably free from adsorbed water and if necessary are dried as by heating to an elevated temperature, e.g. above 200°C.

The inorganic support is added to the alkanol solution containing magnesium alkoxide and, after mixing, the alkanol solvent is evaporated. The alkanol is evaporated at or about the normal boiling point of the alkanol at ambient pressure or at a lower temperature at reduced pressure until the resulting powder appears to be dry. If necessary, the powder may be washed with a hydrocarbon solvent, e.g. isooctane, to ensure that the alkanol has been removed. This method of providing procatalyst precursor is described in more detail in US-A-4,771,024.

Yet another method by which the alkanol solution is employed to produce a magnesium alkoxide solid is the process termed spray cooling. In this conventional procedure a hot, concentrated solution of the magnesium alkoxide-acid adduct in alkanol is passed rapidly into a chilled liquid with which the alkanol is largely immiscible. Hydrocarbon fractions such as kerosene are often used for this purpose. The rapid cooling and supersaturation of the alkanol solution results in the production of solid, spheroidal particles containing magnesium alkoxide, which particles are of substantially uniform size and are substantially free from fines.

By whatever method the magnesium alkoxide-containing particles are produced, the olefin polymerization procatalyst is produced therefrom by conventional procedures such as by treatment of particles with titanium tetrachloride in solution in a halohydrocarbon solvent such as chlorobenzene and an electron donor such as a phthalate ester. In turn, the procatalyst thereby produced is contacted with a triethylaluminum cocatalyst and a conventional selectivity control agent and the resulting catalyst is employed in the polymerization of olefins such as ethylene or propylene.

The catalysts produced in this way provide high catalytic activity and in the case of propylene or higher α -olefins provide an acceptable selectivity to stereoregular product. The advantages of employing the magnesium containing procatalyst precursors prepared in accordance with the invention are most apparent, however, in the morphology of the polymer product. In the case of the polymerization of propylene, for example, the polypropylene product is obtained as substantially uniform spherical particles with the substantial absence of fines or other materials of undesirably small particle size.

The invention is further illustrated by the following Examples.

EXAMPLE I

A 10.0 g (87 mmol) quantity of magnesium ethoxide, 25.5 g (175 mmol) of triethylborate and 110 ml of ethanol were mixed at room temperature (27°C). After 10 minutes the temperature had risen to 34°C and after 1 hour without heating a cloudy solution was obtained in which the molar ratio of boron:magnesium was approximately 2.0/1. A further 14 g (122 mmol) of magnesium ethoxide was added and the resulting mixture was heated in an oil bath maintained at 57°C while being stirred. The resulting solution was clear and no precipitate formed while the solution stood overnight at room temperature. Analysis of this solution indicated a magnesium content of 2.6% by weight based on total solution and a boron content of 1.04% by weight on the same basis. The final calculated molar boron:magnesium ratio was 0.9/1.

The triethylborate used in this and other Examples was produced by the novel process of slurrying 507 g (7.28 mole) of boric oxide in tetraethylorthosilicate (2941 g, 14.1 mole). The mixture was heated, while being stirred, until distillation began. After a small amount of an ethanol azeotrope and some unidentified material was distilled and collected at 75°C to 90°C, about 2 liters of triethylborate was collected at 105°C to 125°C. The product was analyzed and found to contain 6.0% boron, thereby indicating that the product was 81% triethylborate. (The 19% ethanol is a consequence of moisture from the extremely hygroscopic B_2O_3).

EXAMPLE II

A mixture of 10.8 g (94 mmol) of magnesium ethoxide, 10.8 g (74 mmol) of triethylborate and 10.9 g of ethanol was held overnight in an oil bath maintained at 80°C. The magnesium content of the resulting clear solution was 7.1% by weight and the molar boron:magnesium ratio was 0.8. Upon cooling to room temperature the mixture became viscous but was still pourable. Upon standing for 1 week at room temperature some crystals had formed but no precipitate was present when the solution was diluted with ethanol to 6% by weight magnesium.

10 EXAMPLE III

A 21.2 g (185 mmol) quantity of magnesium ethoxide was slurried in 104 g of ethanol and 19.3 g (185 mmol) of trimethylborate containing some methanol was added. The resulting reaction was noticeably exothermic as about 90% of the magnesium ethoxide went into solution without heating. The mixture was then warmed to about 70°C to yield a cloudy solution. Upon standing overnight at room temperature, no precipitation occurred. The magnesium content of the solution was 3% by weight and the molar boron:magnesium ratio was 1.0.

When this experiment was repeated with a 10% additional quantity of methyl borate being present, the amount of solid remaining undissolved without heating was again about 10%.

Trimethylborate was produced by the general procedure described above for triethylborate except that tetramethylorthosilicate was used instead of the corresponding ethyl material. The trimethylborate produced contained 9.6% boron, thus indicating a product containing 92% trimethylborate.

EXAMPLE IV

A 5.55 g (0.23 mole) quantity of 50 mesh magnesium metal and 25 g (0.17 mole) of triethylborate were slurried in 50 g of ethanol. About 0.5 g of 10% ferric chloride in ethanol and 0.12 g of bromine were added and the slurry was allowed to stand until effervescence became vigorous (about 10 minutes). Over the next 20 minutes another 50 g of ethanol were added. The reaction was allowed to continue overnight without heating but with stirring. After adding additional ethanol to replace that which had been lost during the vigorous ebulliation, the mixture was heated for about one hour to dissolve the last few magnesium granules and the cloudy solution was filtered through a medium porosity fritted glass disk to remove 0.2 g of a grey solid. A moderately viscous, clear solution was obtained with a magnesium content of about 4.1% and a molar boron:magnesium ratio of about 0.8.

35 EXAMPLE V

Magnesium ethoxide (40 g, 0.35 mole) was slurried in 300 g of ethanol and sulfur dioxide was bubbled through the slurry. Over four minutes, 21.5 g (0.34 mole) of sulfur dioxide was added to the ethanol mixture. The hot mixture was allowed to cool and it was observed that substantially all of the magnesium ethoxide had dissolved. The bubbling of sulfur dioxide was resumed and 30.9 g (0.27 mole) of additional magnesium ethoxide was added. After a total of 80.3 g (1.2 mole) of sulfur dioxide had been added to the ethanol mixture a clear solution was obtained. The magnesium content of the solution was 3.52% and the sulfur dioxide:magnesium ratio was 2.0.

45 EXAMPLE VI

Magnesium ethoxide (10 g, 87 mmol) and aluminum ethoxide (28.6 g, 176 mmol) were slurried in 230 g of ethanol. No reaction was observed at room temperature but as the temperature of the mixture was raised to 63°C an opalescent solution was obtained. An additional 10 g (87 mmol) of magnesium ethoxide was added and dissolved after stirring at 63°C for over 1 hour. The magnesium content of the solution was 1.5% and the molar aluminum/magnesium ratio was 1.0.

EXAMPLE VII

Magnesium metal (50 mesh, 9.65 g, 0.4 mole) and aluminum metal (20 micron powder, 10.75 g, 0.4 mole) were slurried in 55 g of ethanol. About 1 ml of 10% ferric chloride in ethanol and 2 drops of bromine were added and the slurry was allowed to stand until the effervescence became vigorous in about 10 minutes. Over the next 10 minutes 240 g of additional ethanol were added. The reaction was allowed to proceed while being stirred

but not heated until no further hydrogen evolution was observed in about 3 hours. Additional ethanol was added to replace that lost during the reaction and the resulting cloudy solution was filtered through a medium fritted disk. A moderately viscous, clear solution was obtained with a magnesium content of about 3% and a molar magnesium/aluminum ratio of about 1.0.

EXAMPLE VIII

Magnesium ethoxide (66.3g, 0.58 mole) and paraformaldehyde (30 g, 1.0 mole) were slurried in 303 g of ethanol at room temperature to produce a solution containing 3.5% magnesium with a molar formaldehyde/magnesium ratio of 1.7. When this experiment was repeated using a molar formaldehyde/magnesium ratio of 2, a thick slush was obtained after overnight standing.

EXAMPLE IX

Porous silica spheres obtained from the PQ Corporation (30 micron particle size, pore volume of 2.7 cc/g) were dried in vacuo for 2 days at 300°C. A quantity of 29.3 g of the magnesium solution of Example II was stirred slowly into 10.0 g of the dried silica to produce a material of the consistency of sawdust. The material became a free flowing powder as 1.0 g of ethanol evaporated at ambient temperature. After drying in a stream of nitrogen for 1 hour at ambient temperature the total weight had decreased to 25 g indicating complete loss of ethanol. After standing overnight in a crystallizing dish on a hotplate at about 90°C, the weight decreased to 18.5 g indicating loss of the triethylborate.

A polymerization catalyst was produced from this magnesium ethoxide impregnated silica. The impregnated silica (7.8 g) was stirred with 2.5 ml of diisobutylphthalate in 200 ml of 50/50 by volume titanium tetrachloride/chlorobenzene for 1 hour at 115°C and then filtered while hot. The solids were washed twice with fresh 200 ml portions of the titanium tetrachloride/chlorobenzene mixture and then rinsed once with 150 ml of isooctane at 90°C and then once with isooctane at room temperature for 100 minutes. The resulting dried solid analyzed as follows: 3.81% Ti, 9.14% Mg, 35.2% Cl and 0.57% B. Polymerization was conducted using this procatalyst and a triethylaluminum cocatalyst in liquid propylene with diisobutyldimethoxysilane as a selectivity control agent. The process produced 13.9 kg of polypropylene/g of catalyst in 1 hour at 67°C with xylene solubles of 2.4%.

EXAMPLE X

By the procedure of Example IV a series of three solutions was produced wherein each contained 0.8 equivalent of triethylborate per equivalent of magnesium ethoxide. To each of two of the solutions was added a small amount of AEROSIL®, a commercially available fumed silica which served to provide better surface properties to the solids obtained upon spray drying of the solutions. Each solution was diluted to about 2% by weight of magnesium and spray dried at 100°C using conventional spray drying equipment. The composition of the spray dried products is shown in Table I.

TABLE I

Sample	% AEROSIL®	Solids Composition		Solids Description
		% Mg	% B	
A	0	14.1	2.0	Spherical to Shrunken Pea
B	3.5	11.9	1.9	Spherical to Shrunken Pea
C	1.75	13.2	1.6	Spherical to Shrunken Pea

Polymerization procatalysts were prepared from the spray dried solids. An amount of each solid containing 50 mmol of magnesium was stirred with 1.9 ml of diisobutylphthalate in 150 ml of 50-50 (by volume) titanium tetrachloride-chlorobenzene for 1 hour at 115°C and then filtered while hot. The solids were washed twice with fresh 150 ml portions of the TiCl₄-chlorobenzene mixture, rinsed once with 15 ml of isooctane at 90°C, twice with isooctane at room temperature and then dried under a nitrogen stream for 100 minutes. The composition of the solids is shown in Table II. Each of the procatalysts had the general appearance of a shrunken pea.

TABLE II

Procatalyst Sample	Solids Composition			
	% Ti	% Mg	% Cl	% B
A	2.8	16.1	54.4	1.9
B	1.7	12.7	41.3	1.5
C	1.6	14.4	47.4	1.6

The analysis of chlorine content as a function of the titanium and magnesium content indicates that essentially all of the chlorine is associated with titanium and magnesium and the boron is present as a borate ester and not as a boron chloride species.

Employing each of the above procatalysts, polymerization of propylene was conducted in liquid propylene using triethylaluminum as co-catalyst and diisobutyldimethoxysilane as the selectivity control agent. The catalyst activity in each case was comparable to a conventional olefin polymerization catalyst and the polypropylene product comprised substantially uniform spherical particles with few, if any, fines.

EXAMPLE XI

Polymeric magnesium methoxide ($[\text{Mg}(\text{OMe})_2]_n$) was prepared by evaporation of methanol from commercial 8% $\text{Mg}(\text{OMe})_2$ under a stream of nitrogen then heating the solid at 170°C for 2 days. The solids were washed twice with warm methanol to remove any soluble, non-polymerized material then washed with isooctane then dried under a stream of nitrogen.

7.2 g of trimethylborate (69.5 mmol) was added to 6.0 g of the insoluble $[\text{Mg}(\text{OMe})_2]_n$ (69.5 mmol) slurried in 35 g of methanol. The mixture was warmed to about 60° to obtain a thick slush. Addition of another 3.7 g of trimethylborate (36 mmol) to the warm mixture produced a cloudy solution with some solids present. After a total of 14.4 g of trimethylborate (139 mmol) had been added a slightly cloudy solution (with about 0.2 g of solids present) was obtained. Upon standing overnight all of the solids had settled to yield a perfectly clear solution. Mg content was about 3.0%.

EXAMPLE XII

A solid crystalline material was first prepared according to US-A-4,855,371. Trimethylborate (147 g of a 90% solution, 1.27 mol) was dissolved in 1.5 liter of MeOH, under nitrogen, in a 3 liter, 3 neck flask. Magnesium turnings (30.9 g, 1.27 mol) were added to the rapidly stirring solution, in 7 portions, over about 2 hours (to moderate the rate of hydrogen evolution). After the sixth portion of Mg was added, precipitation began. The final slurry was refluxed for 3 hours then cooled to room temperature and filtered. After washing with isooctane and drying in a stream of nitrogen, 147 g of white, granular particles were obtained, in the 10-50 μm size range. Analysis: 11.3 % Mg, 2.36% B. A second crop of granular particles of nearly uniform particle size was obtained by adding another 30.9 g of magnesium turnings to the filtrate from above. Yield 262 g. Analysis: 13.7% Mg, 2.6% B. (This crystalline material was insoluble in methanol.)

A portion of this crystalline material (10 g, 56.5 mmol Mg) was slurried in 25.3 g of methanol at room temperature then trimethylborate (92%, 13.3 g, 118 mmol) was added to produce a clear solution. Mg content was about 3.0%.

EXAMPLE XIII

A solid crystalline material was first prepared according to US-A-4,855,371. Magnesium methoxide (12% in methanol, stabilized with 0.125 equivalent of tetramethoxysilane) was added to 0.5 equivalent of 2-methyl-resorcinol (10% in methanol) to produce a crystalline precipitate (which was insoluble in methanol).

A portion of this crystalline material (8.5 g, 40 mmol Mg) was slurried in 28.5 g of methanol then trimethylborate (92%, 9.0 g, 80 mmol) was added to give a clear, orange solution. Mg content was about 2.1%.

EXAMPLE XIV

Borate catalyst production was done in three separate phases. A triethylborate/magnesium ethoxide complex solution was prepared, the solution was spray dried to yield the catalyst support, and the support was metathesized to finally produce the catalyst.

In this example, 181 g of Mg metal flakes were added to 5950 g of dry ethanol. The ethanol was dried to less than 50 ppmw moisture using Linde 4A molecular sieves. Ferric chloride dissolved in ethanol, equivalent to a Fe/Mg molar ratio of 0.005 was added to the vessel. Triethylborate (1101 g) was added to the reactor at room temperature. During this addition, the temperature of the vessel contents increased from 23.8°C to 36.4°C. The reactor contents were heated to 80°C and held at this temperature for four hours. The solution was cooled to 40°C prior to discharging it through 10 micron filters. The analysis of the solution indicated a Mg content of 2.67 wt%. The above solution composition was adjusted to contain 2 wt% Mg and 3.5 wt% AEROSIL R-972 @ hydrophobic silica. This was done by adding a mixture of 6033 g of the above solution and 1736 g of dry ethanol to 283 g of AEROSIL R-972 @ hydrophobic silica. The mixture was stirred for 20 minutes at 40°C to ensure a uniform slurry composition.

The resulting slurry was spray dried under inert conditions using a Buchi laboratory spray dryer which operates inside a specially designed drybox. The spray drying conditions for preparing the support are given below:

Drying Gas = Nitrogen
 Inlet Drying Gas Temperature = 120°C
 Atomizer Gas Feed Rate = 800 cm³/min Aspirator Rate = Approx. 0.0126 m³/s (27 scfm)
 Slurry Feed Rate = 20 cm³/min
 Atomizer Nozzle Size = 0.5 mm

The spray dried support contained 15.7 wt% Mg.

The support was converted to a polypropylene catalyst by a method similar to those previously described. The procedure began by adding 563.5 g of the above spray dried support to 13.4 kg of a 50:50 volume mixture of TiCl₄ and dry monochlorobenzene (CB) which contained 131.8 g of diisobutyl phthalate (DIBP). The DIBP/Mg molar ratio was 0.13. The addition was done at 20°C. This reaction mixture was held at 20°C for 15 minutes before the temperature was ramped to 50°C for a 30 minute hold. Following this hold, the reaction mixture temperature was increased to 110°C and held there for one hour. The solids were separated from the liquid by filtration and then mixed with fresh CB.

The concentrated slurry was added to 12.2 kg of a 50:50 volume mixture of TiCl₄ and CB which contained 31.8 g of phthaloyl dichloride. The mixture was heated to 110°C and held there for one hour. Again, the solids were separated by filtration and mixed with fresh CB.

This slurry was added to 12.2 kg of a 50:50 volume mixture of TiCl₄ and CB and heated to 110°C and held for 30 minutes. The solids were separated by filtration and then washed with hexane six times on a filter funnel with a coarse porosity frit. Each wash consisted of 1500 ml of dry hexane. The solids were dried on the frit and then mixed with twice their mass of Kaydol mineral oil. The yield of the dry solids was 697 g. The Mg and Ti content of the washed product was 13.26 wt% and 1.86 wt% respectively.

Claims

1. An alkanolic solution of an adduct of magnesium alkoxide and an acid selected from sulfur dioxide, formaldehyde, aluminium alkoxide and trialkylborate, wherein the molar ratio of acid:magnesium alkoxide is from 0.4/1 to 2/1 and the concentration of magnesium is from 1% to 8% by weight based on the weight of the solution.
2. A solution according to claim 1 wherein the magnesium alkoxide is magnesium methoxide or magnesium ethoxide.
3. A solution according to claim 1 or 2 wherein the alkanol is ethanol.
4. A solution according to claim 1, 2 or 3 wherein the acid is an aluminium alkoxide of formula Al(OR)_3 wherein each R independently is alkyl of from 1 to 10 carbon atoms.
5. A solution according to claim 4 wherein R is ethyl.

6. A solution according to claim 1, 2 or 3 wherein the acidic material is a trialkylborate of formula
$$\text{B(OR)}_3$$
wherein each R independently is alkyl of from 1 to 10 carbon atoms.
- 5 7. A solution according to claim 6 wherein the trialkylborate is trimethylborate or triethylborate.
8. A solution according to claim 6 or 7 wherein the molar ratio of trialkylborate/magnesium is from 0.8/1 to 2/1.
- 10 9. A solution according to any one of the preceding claims wherein the concentration of magnesium is from 2% to 6% by weight based on the weight of the solution.
10. A process for producing a solution as claimed in any one of the preceding claims, which process comprises contacting the magnesium alkoxide and alkanol in the presence of said acid, such that the resulting solution has an acid/magnesium molar ratio of from 0.4/1 to 2/1.
- 15 11. A process according to claim 10 wherein the magnesium ethoxide is obtainable by reacting elemental magnesium and ethanol.
- 20 12. A process for the production of a mixture of solid, substantially uniform spheroidal particles substantially free of fines containing magnesium alkoxide which process comprises 1) spray drying the alkanol solution as claimed in any one of claims 1 to 9 or 2) impregnating solid inorganic oxide spheroidal particles with the alkanol solution as claimed in any one of claims 1 to 9.
- 25 13. A process according to claim 12 wherein no more than 1% of the particles has a size outside the range from 8 to 100 μm .

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